Neutron Transmutation of ^{10}B doped Diamond

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Abstract

Free standing ^{10}B isotope doped diamond films deposited by chemical vapor deposition in a microwave chamber were irradiated to thermal neutron fluence values of $0.32x10^{19}$, $0.65x10^{19}$, $1.3x10^{19}$, and $2.6x10^{19}$ n/cm^2. Cooling of the diamond films was maintained during irradiation. Neutron irradiation to a fluence of 10^{20} n/cm^2 of fast and thermal neutrons was also performed on a diamond epilayer without cooling. The films were characterized by Raman, FTIR, and photoluminescence spectroscopy for defect generation and non-diamond phase formation. The crystalline quality of diamond was characterized by X-ray diffraction. Electrical characterization was performed by measuring conductivity over the temperature range of 150 to 630 K using Van der Pauw set up. It is concluded that transmutation of ^{10}B to ^{7}Li can be carried out without the formation of irrecoverable damage by irradiation with low fast neutron and high thermal flux and continuous cooling of diamond films.

Characterization by spectroscopy

It was found that defect configurations in diamond responsible for increase in continuum back ground in the one-phonon region of Raman spectrum were absent in the films that have been cooled during irradiation, as shown in figure 1. Absence of characteristic infrared absorption peaks that were observed only upon annealing neutron-irradiated diamond is used to conclude that the temperature of the samples during irradiation was well below that needed for mobility of defects and accumulation of stable unrecoverable damage. On the other hand, results from diamond epilayer subjected to equal thermal and fast neutron fluence close to 10^{20} n/cm^2 and without cooling showed that defects formed from displaced carbon atoms become mobile and form complex configurations of irrecoverable damage. The temperature rise in the neutron-irradiated sample from transmutation was modeled and found to reach high values in the absence of cooling and as a result of reduced thermal conductivity of diamond.

Electrical characterization

From the measurement of electrical conductance of the unirradiated and 400 hr and 800 hr irradiated diamond samples, a decrease in conductance with lower value of activation energy was observed in the irradiated samples compared to that in the unirradiated, as shown in figure 2 [1]. The electrical conductivity could not be associated with a single activation process and it is thought to arise from different mechanisms. Further detailed characterization and annealing of the irradiated sample is continued.

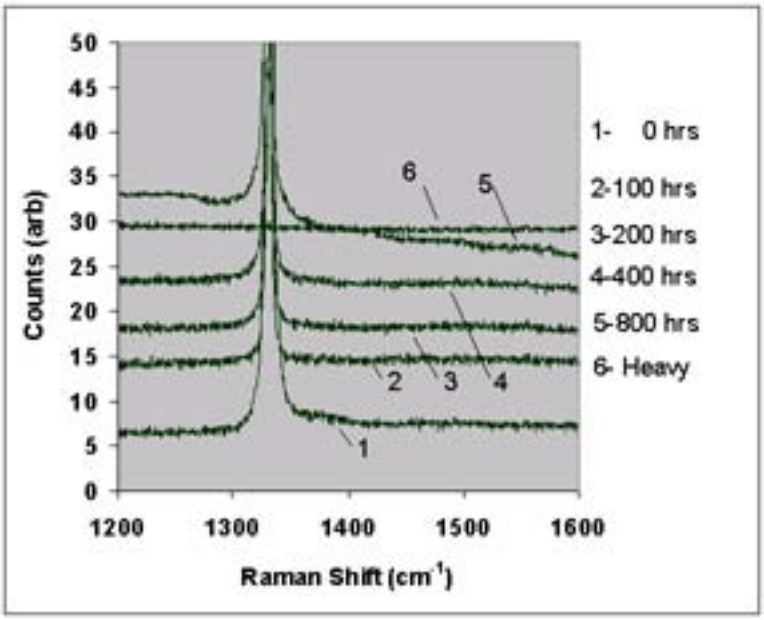

Figure 1. Raman spectrum from the unirrdiated and neutron irradiated samples with a thermal flux of 9.0×10^{12} $n.cm^{-2}s^{-1}$ and different irradiation periods is shown. Fluence values are given in the text.

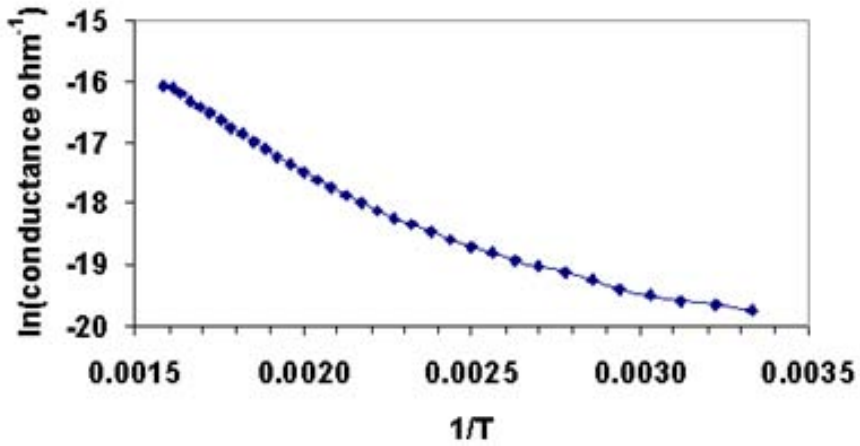

Figure 2. Electrical conductance of 800 hr neutron irradiated sample of ^{10}B isotope doped diamond sample.

References

[1]. M. L. Reed et al., J. Vac. Sci. Technol., 2004, v. 22A, p. 1191.